out the system. For a particulate limestone feed having a particle size less than 20 mesh (60 mesh is optimal), a suitable entraining gas velocity is approximately 20 m/sec. As design operating temperatures vary, the size of the conveying system and optimal gas velocity would vary accordingly.

The reactor **14** consists of a high-temperature alloy, vertical pipe located inside the feed silo, operating at sufficiently high temperatures to calcine the feed material. The reaction zone may extend into the cyclone separator **20**. As mentioned above, the feed material is discharged from the silo's storage compartment into the feed pipe **44** through rotary valves **30** and pneumatically conveyed tangentially into the calcining zone of the reactor **14**, thus producing a cyclonic action that characterizes the flow of the fluidized reactants during calcination. In order for the decomposition reaction of limestone to take place, a reactor temperature of at least 1,700° F. must be maintained, possibly avoiding temperatures higher than 2,450° F. to prevent sintering. The heat required to reach and maintain these temperatures is provided first by the pre-heating steps and then by the gas burner in the reaction zone. The tangential flow of the feed into the calcining pipe provides the gradual blending of the feed material with the hot combustion gases, which results in avoidance of sintering of the feed material. The cyclonic action also increases the velocity of the fluidized particles for a given throughput and a given retention time in the reactor due to the spiral path that the material must follow. As a result, larger particles migrate closer to the pipe wall and travel more slowly than smaller particles, thereby enabling the complete and uniform calcination of such coarser feed material. At the same time, the cyclonic action causes the finer material, which is calcined more rapidly than coarser material, to exit the reactor at a greater rate, which is all consistent with obtaining a product of uniform quality.

The fuel source that is best suited for this application is natural gas, although a wide variety of fuels can be utilized. The proper air-to-gas ratio for proper combustion of natural gas is roughly 12 to 1. It is recommended to control the reactor temperature by using the solid-particle feed rate, rather than gas rate, because control of the temperature using fuel-to-air ratios may lead to inefficient fuel consumption and unacceptable emissions. Excess air entering the system with the raw material pneumatic feed can be useful when calcining material with organic impurities that require additional air for complete combustion. If necessary, additional fuel can be added to the air stream to compensate for any excess and to balance the air-to-fuel ratio to the desired value.

The calcination products exit the vertical calcining reactor **14** and travel through the high temperature cyclone **20**, which is located in parallel to the calcining pipe. It is important to maintain calcination temperatures in the cyclone to avoid any adverse recarbonation of the solid oxide material prior to its separation from the combustion gases. Depending on the physical characteristics of the calcined material, it may be necessary to include a means for reducing calcined oxide buildup on the inner walls of the cyclone. This can be accomplished effectively with an alloy chain suspended from a swivel at the center of the cyclone discharge.

The calcined product is discharged at the bottom of the cyclone through the rotary valve **22**, while the hot exhaust gases exit the top of the cyclone and then travel through the gas-to-air primary and secondary heat exchangers **24**,**26**. These exchangers are also preferably located in parallel to the cyclone **20** and the calcining pipe **14**. The primary heat exchanger **24** provides the initial cooling of the exhaust gases while preheating the feed air to the system. The secondary heat exchanger **26** further cools the exhaust gases while preheating the conveying air used to fill the silo and to fluidize the particles at the bottom of the silo. All of these components are located within the storage silo and completely surrounded with feed material, which provides the necessary heat transfer between the hot calcining components and the feed material to keep the entire system within a uniform and acceptable temperature range for optimal calcination. This arrangement also avoids the need for expensive refractory material to insulate the equipment.

The calcined oxide product, discharged from the cyclone through the rotary valve **22**, can be mechanically or pneumatically conveyed to its destination. Alternatively, the calcined material can be hydrated immediately after discharge and the resultant slurry pumped to the end use point.

Thus, the present invention provides a self-contained, energy-efficient system for calcining particulate feed material in a continuous operation that features high-temperature operating units (calcining reactor, cyclone, heat exchangers) located inside the raw material silo for insulation and preheating, which eliminates the need for refractory insulation, and a high level of energy recovery from the heat exchangers used to preheat the feed and the conveying air to the silo. Because of its configuration, the calcining plant of the invention is suitable for modular construction and for skid-mounting, so that it can be easily assembled and moved. The placement of the multiple rotary valve feeders at the bottom of the silo permit maintenance without shutdown of the plant. Various types of burners can be used and easily switched to utilize a wide range of fuels (i.e., gas, fuel oil, coal). Because of its high resistance to thermal shock resulting from its concept of construction, the plant requires short start-up and shut-down times. If necessary, the option of mixing of the feed material with dry recycled feed material from the silo to lower the moisture content to a level sufficient for pneumatic conveying is easily implemented. Similarly, a supplemental burner can easily be introduced in conjunction with the preheated conveying air to increase the drying capacity of the system. Finally, as a result of its simplicity and high efficiency, the calcination plant of the invention is relatively inexpensive to construct and operate.

Blower size, fuel requirements, pipe and channel/conduit sizes, and similar manufacturing parameters for a specific product and a desired throughput are well within the design choices of those skilled in the art. Obviously, the actual system capacity will vary due to unpredictable variables such as heat loss, impurities, pressure, and retention time. However, adjustments can be made to obtain the desired capacities by changing the size, length, and even the number of burners in the system to compensate for these variables.

Various changes in the details, steps and components that have been described may be made by those skilled in the art within the principles and scope of the invention herein illustrated. Therefore, while the present invention has been shown and described herein in what is believed to be the most practical and preferred embodiments, it is recognized that departures can be made therefrom within the scope of the invention, which is not to be limited to the details disclosed herein but is to be accorded the full scope embraced by any and all equivalent processes and products.

I claim:

1. A calcination plant for a particulate feed material comprising:

a storage silo for the feed material;

a calcination reactor;

a solid-gas separation unit;

and first means for fluidizing said particulate feed material from the silo and for sequentially conveying a resulting fluidized feed stream through the reactor and separation unit to produce a solid calcined product and a gaseous exhaust;

wherein said reactor and separation unit are enclosed in the storage silo and immersed in the particulate feed material stored therein.

2. The plant of claim 1, further comprising a first heat exchanger between said gaseous exhaust and a reactor air stream used for fluidizing the particulate feed material conveyed to the reactor.

3. The plant of claim 1, further comprising second means for fluidizing the particulate feed material prior to storage and for conveying a resulting fluidized feed stream to the storage silo.

4. The plant of claim 3, further comprising a second heat exchanger between said gaseous exhaust and a feed air stream used for fluidizing the particulate feed material conveyed to the silo.

5. The plant of claim 1, further comprising second means for fluidizing the particulate feed material prior to storage and for conveying a resulting fluidized feed stream to the storage silo; comprising a first heat exchanger between said gaseous exhaust and a reactor air stream used for fluidizing the particulate feed material conveyed to the reactor; and a second heat exchanger between said gaseous exhaust and a feed air stream used for fluidizing the particulate feed material conveyed to the silo.

6. The plant of claim 5, wherein said first and second heat exchangers are enclosed in the storage silo and immersed in the particulate feed material stored therein.

7. The plant of claim 1, wherein said solid-gas separation unit includes a cyclone.

8. The plant of claim 6, wherein said solid-gas separation unit includes a cyclone.

9. The plant of claim 1, wherein said calcination reactor has a substantially cylindrical bottom portion including a fuel burner and said fluidized feed stream is introduced tangentially in the bottom portion such as to produce a cyclonic flow through the reactor.

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~~10. The plant of claim 9, wherein said calcination reactor has a substantially cylindrical bottom portion including a fuel burner and said fluidized feed stream is introduced tangentially in the bottom portion such as to produce a cyclonic flow through the reactor.~~

11. The plant of claim 1, wherein said first means for fluidizing said particulate feed material from the silo and for sequentially conveying a resulting fluidized feed stream through the reactor and separation unit comprises at least one positive displacement blower.

12. The plant of claim 10, wherein said first means for fluidizing said particulate feed material from the silo and for sequentially conveying a resulting fluidized feed stream through the reactor and separation unit comprises at least one positive displacement blower.

13. The plant of claim 11, wherein said first means for fluidizing said particulate feed material from the silo and for sequentially conveying a resulting fluidized feed stream through the reactor and separation unit further comprises at least one variable-speed draft fan for said gaseous exhaust.

14. The plant of claim 1, wherein said first means for fluidizing the particulate feed material from the silo comprises a least one rotary valve for delivering the feed material from the silo into a conduit to produce said fluidized feed stream.

15. The plant of claim 13, wherein said first means for fluidizing the particulate feed material from the silo comprises a least one rotary valve for delivering the feed material from the silo into a conduit to produce said fluidized feed stream.

16. The plant of claim 1, further comprising means for injecting a silo air stream into the silo in order to promote uniform flow of the feed material out of the silo.

17. The plant of claim 15, further comprising means for injecting a silo air stream into the silo in order to promote uniform flow of the feed material out of the silo.

18. The plant of claim 16, wherein said silo air stream is pre-heated by heat exchange with said gaseous exhaust.

19. The plant of claim 17, wherein said silo air stream is pre-heated by heat exchange with said gaseous exhaust.

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